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Metabolic Equivalents for Post-Myocardial Infarction Patients during a Graded Treadmill Walking Test

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ABSTRACT

Meadows S, Woolf-May K, Kearney E. Metabolic Equivalents For Post-Myocardial Infarction Patients during a Graded Treadmill Walking Test. **JEPonline** 2013;16(2):60-69. The current compendium regarding resting metabolic equivalents (METs) is based on 1 MET: oxygen uptake (VO_2) 3.5 mL·kg^{-1}·min^{-1} is used to understand and define energy expenditure, aerobic capacity, and exercise intensity in cardiac populations. Yet, a field test has indicated it is not sufficiently accurate and may lend itself to implications that are potentially hazardous. Therefore, the aim of this study was to determine METs in post-MI males during a controlled graded treadmill walking test (GTWT) using a comparative controlled study design. Seventeen male post-myocardial infarction (MI) subjects (mean ± SD, 63.0 ± 8.5, range 48 to 77 yrs) and 17 healthy male controls (51.9 ± 7.7, range 41 to 66 yrs) participated as subjects in this study. All subjects performed a GTWT at speeds 2.0 to 4.4 m·hr^{-1}. Throughout the testing, the subjects' VO_2, heart rate, and rating of perceived exertion (RPE) were measured. Analysis comparing lines of regression showed that the METs were significantly higher ($P<0.05$) for post-MIs *vs.* the controls. METs differed significantly for post-MIs *vs.* current compendium METs ($P<0.01$), and controls vs. current compendium METs ($P<0.01$). Given that both post-MIs and controls showed significantly higher METs *vs.* the current compendium values during a GTWT, these findings bring into question the appropriateness of the standard use of the current METs in this context.

Key Words: Cardiac Rehabilitation, METs, Exercise Prescription

INTRODUCTION

The idea of using multiples of resting metabolic rate to describe different intensities of physical movement is by no means recent, as Howley (13) refers to the use of such a concept as far back as 1890. Prior to the use of the current resting 1 metabolic equivalent (MET) of 3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ (2), there have been a number of different computations (10) to define resting metabolism. Interestingly, Byrne et al. (10) stated that it is not clear how or when the 1 MET value of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ was derived. Yet, it is a common practice for researchers to use the MET values of various activities (15) in different populations (20) with the understanding that the values are based on the 1 MET value of 3.5 $mL \cdot kg^{-1} \cdot min^{-1}$ that was originally obtained from the resting oxygen uptake (VO_2) of one 70 kg male of 40 yrs of age (13,28). Given the seemingly scant scientific evidence for the origin of this value, it is hard to believe how this figure has managed to achieve such widespread acceptance and application.

The original intent for METs was as an activity classification system to standardize exercise intensities in survey research (1,2) and not, as it is often used today, to define energy expenditure, functional (aerobic) capacity, or physical activity (PA)/exercise intensity. METs are also widely used in the prescription of PA/exercise intensity for a range of populations. Despite criticism by numerous researchers, (10,11,17,20,24) the use of METs is widely used to determined the functional capacity for risky populations such as cardiac patients (3,6,9).

Byrne et al. (10) looked at the resting metabolic rate (RMR) of 156 men and women with a mean age of 38.3 yrs and a body mass index (BMI) of 31.2 and found that RMR was 2.56 $mL \cdot kg^{-1} \cdot min^{-1}$, which is considerably less than the accepted Compendium 1 MET value. In addition, Woolf-May and Ferrett (29) observed that during an incremental 10-m shuttle walking field test (26), a group of male post-myocardial infarction (MI) patients showed significantly greater MET values when compared to healthy age-matched male controls when using standard METs for walking at the same speed (4). This finding further questions the use of the current Compendium METs in specific populations.

Therefore, given the potential risks of using none populations specific METs, the purpose of this study was to further investigate the MET values of cardiac patients using the current Compendium 1 MET and determine if this value differed from the current published Compendium of Physical Activity values (2) during a controlled laboratory based GTWT.

METHODS

Subjects

Seventeen uncomplicated non-smoking post-MI males were recruited from local phase IV exercise cardiac rehabilitation (CR) groups in the Medway, Kent area (UK). Phase IV is where cardiac patients are deemed sufficiently stable and able to exercise independently within the community. Seventeen apparently healthy non-smoking controls were also recruited from the same area. Interested individuals were sent an information sheet and were required to self-complete a health and PA screening questionnaire. Volunteers were excluded if they failed to understand the nature of the study and/or failed to gain their GPs approval to participate. Once approved, and prior to any assessments, written informed consent was obtained. The local NHS and Canterbury Christ Church University Research Ethics Committees approved this study. Subject characteristics are displayed in Table 1.

Assessments

Assessments were scheduled for early afternoon (30). The subjects were informed that during the 24 hrs preceding assessments they were not to undertake vigorous PA/exercise or consume alcohol, nor to eat and/or consume caffeine during the preceding 2 hrs; drinking water was permitted. Where relevant, subjects were instructed to take their medications as usual.

On two separate occasions each subject visited the Exercise Testing Laboratory at the University of Kent, Medway campus. Visit 1 was for protocol familiarization and to ask questions. On arrival each subject's height (Stadiometer Seca 220, Hamburg, Germany) and weight (Seca 710, Hamburg, Germany) were measured, body mass index (BMI) was calculated. Each subject then sat quietly for 10 min, resting blood pressure (BP) (Yamasu Mercurial Spygmomanometer 605P, Kenzmedico, Japan) and heart rate (HR) (beat·min^{-1}) (Polar Model S810, Kempele, Finland) were recorded. The subjects were not permitted to perform the GTWT if BP exceeded 180 mmHg systolic (SBP) and 100 mmHg diastolic (SBP) or resting HR > 100 beats.min^{-1} (5).

Table 1. Subject Characteristics at Baseline, Mean ± SD [Range].

Variables	Post-MIs (N =17)	Controls (N =17)
Age (yrs)	**63 ± 8.50 [48 - 77]	51.9 ± 7.70 [41 - 66]
Height (m)	1.76 ± 0.05 [1.64 - 1.84]	1.77 ± 0.04 [1.73 - 1.79]
Body mass (Kg)	*88.8 ± 13.4 [64.0 - 111.8]	79.2 ± 11.9 [6.5 - 105.5]
BMI (kg·m^{-2})	*28.6 ± 4.30 [20.5 - 38.7]	25.4 ± 4.10 [20.8 - 35.6]
Pre-exercise resting SBP (mmHg)	127.9 ± 11.1 [96 - 150]	130.5 ± 14.1 [108 - 154]
Pre-exercise resting DBP (mmHg)	76.8 ± 11.5 [62 - 110]	83.4 ± 10.6 [66 -102]
PA·wk^{-1}		
• 30 min sessions at moderate intensity	**4.59 ± 1.42 [2 - 7]	2.82 ± 1.78 [0 - 5]
• 20 min sessions at vigorous intensity	2.41 ± 1.58 [0 - 6]	2.06 ± 1.98 [0 - 5]
Alcohol (units·wk^{-1})	1.82 ± 1.24 [0 - 4]	1.71 ± 1.25 [0 - 4]
Medication	**N**	**N**
Aspirin	12	
Clopidogrel	3	
β-blocker	13	
Statin	17	1
Cholesterol absorption inhibitor	1	
ACE inhibitor	14	1
Angiotensin receptor antagonist	1	
Calcium channel blocker	2	
Potassium channel activator	1	
Nitrate	1	

*Significantly different at P<0.05 from the controls. **Significantly different at P<0.01 from the controls.

Graded Treadmill Walking Test (GTWT)

The GTWT protocol was devised to be within the subject's functional capacity, taking into account their age, estimated physical fitness and underlying disease (3) and to facilitate a steady state, which has been shown to take around 2 to 3 min (12,25,27). It has been identified that where there are large increments in the stages of a graded exercise test and/or if the participant is in poor physical condition, there are difficulties for VO_2 to keep pace with each stage of the test (27). Therefore, the test was set at 0% gradient and speed increased by 0.3 $m \cdot h^{-1}$ every 3 min from a starting speed of 2.0 $m \cdot h^{-1}$ to 4.4 $m \cdot h^{-1}$ (Table 2). Each subject was fitted with a facemask (Hans Rudolph Adult Mask, 8930 / 8940 Series, Kansas, USA) covering the mouth and nose to collect expired air. Expired air was analysed breath-by-breath using an online system (Quark b^2, Cosmed, Rome, Italy) to determine VO_2. Heart rate was simultaneously recorded by a heart rate monitor (Polar HRM S810, Kempele, Finland). Each subject mounted the treadmill (h/p/cosmos Saturn 4.0, Traunstein Germany) and performed the GTWT without holding onto the handrail. During the GTWT the mean of these variables were recorded during the final minute of each stage and recorded for analysis.

Table 2. Stages of the GTWT Showing Associated Compendium MET Values.

Stage	**Time** (min)	**Speed** ($m \cdot h^{-1}$) ($km \cdot h^{-1}$)	**Compendium METs for walking on firm level surface** (2)
1	0 – 3	2.0 (3.2)	2.50
2	4 – 6	2.3 (3.7)	2.80
3	7 – 9	2.6 (4.2)	3.06
4	10 – 12	2.9 (4.7)	3.24
5	13 – 15	3.2 (5.2)	3.50
6	16 – 18	3.5 (5.6)	3.80
7	19 – 21	3.8 (6.1)	4.52
8	22 – 24	4.1 (6.6)	5.26
9	25 – 27	4.4 (7.1)	6.04

The protocol speeds not reported in Ainsworth et al. (2) were estimated using linear interpolation, METs = 1.2103.m·h-0.104; R^2=0.92.

Since CR patients are frequently prescribed beta-blockers, which reduces their HR, this factor was not relied upon to assess exercise intensity. In accordance with ACPICR (6) guidelines, the Borg 6 - 20 scale (8) subjective ratings of perceived exertion (RPE) were recorded in the final minute of each test stage. In all cases the GTWT was terminated at volitional fatigue.

Statistical Analysis

In order to achieve sufficient participant numbers at an alpha of 5% and 90% power, continual retrospective power analysis was conducted using Clinstat statistical program by Martin Bland (version 08.05.96). This was based on mean inter-group differences at the various GTWT stages of 0.22 ± 0.11 $mL \cdot kg^{-1} \cdot min^{-1}$.

Statistical analysis was carried out using Minitab statistical package (version 16), with a 5% level of significance and variability within a distribution as one standard deviation (mean ± SD). Inter and intra-group differences were compared by one way analysis of variance (ANOVA). The MET versus walking speed relationship was determined using analysis comparing two linear regression lines.

Pearsons Product Moment correlation and regression analyses were used to determine relationships between factors. Guideline MET values were taken directly from compendium values (2) for walking on a firm level surface. Where compendium values did not match the GTWT stage speed values were estimated using linear interpolation (Table 2). Non-parametric alternatives to the above were employed where data failed to be normally distributed.

RESULTS

Cardiovascular Disease Risk Factors (CVD)

Basic analysis of the CVD risk factors include the subjects' family history of death from heart attack by the age 50 yrs, diabetes, elevated BP, elevated total cholesterol, obesity, and smoking. The post-MIs demonstrated a total of 28 while the subjects in the control had a total of 7.

Post-MIs

The subjects were tested at a mean 2.7 ± 1.6 yrs post-MI. None of the medications had any statistically significant effect on VO_2 (mL·kg^{-1}·min^{-1}).

GTWT Post-MIs *vs.* Controls (Table 1)

The post-MI subjects showed significantly higher VO_2 (mL·kg^{-1}·min^{-1}) and METs compared to the controls (F=5.25, P<0.05) and (F=5.25, P<0.05), respectively, at treadmill-walking speeds of 2.0 to 4.4 m·h^{-1} (Figure 1). There were no significant differences in any of the other measured factors P>0.05.

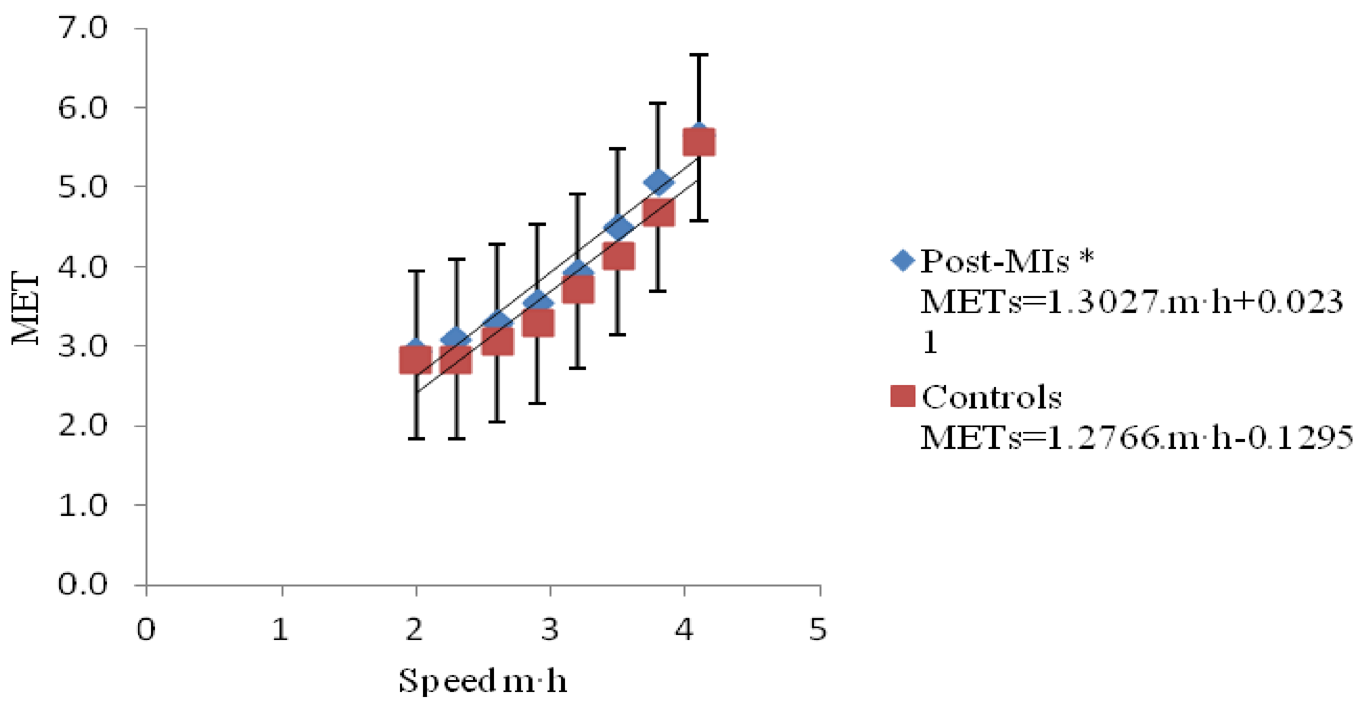

Figure 1. MET vs. Walking Speed Relationship during the GTWT for Post-MIs *vs.* Controls.
*Statistically significantly different from the controls at P<0.05.

GTWT Post-MIs *vs.* Compendium METs

Mean post-MI METs for each GTWT stage was compared to compendium METs of same speed (Table 2, Figure 2). Post-MIs had significantly higher METs (F=31.84, P<0.01).

GTWT Controls *vs*. Compendium METs
Mean control METs for each GTWT stage was compared to compendium METs of same speed (Table 2, Figure 2). Controls had significantly higher METs (F=14.77, P<0.01).

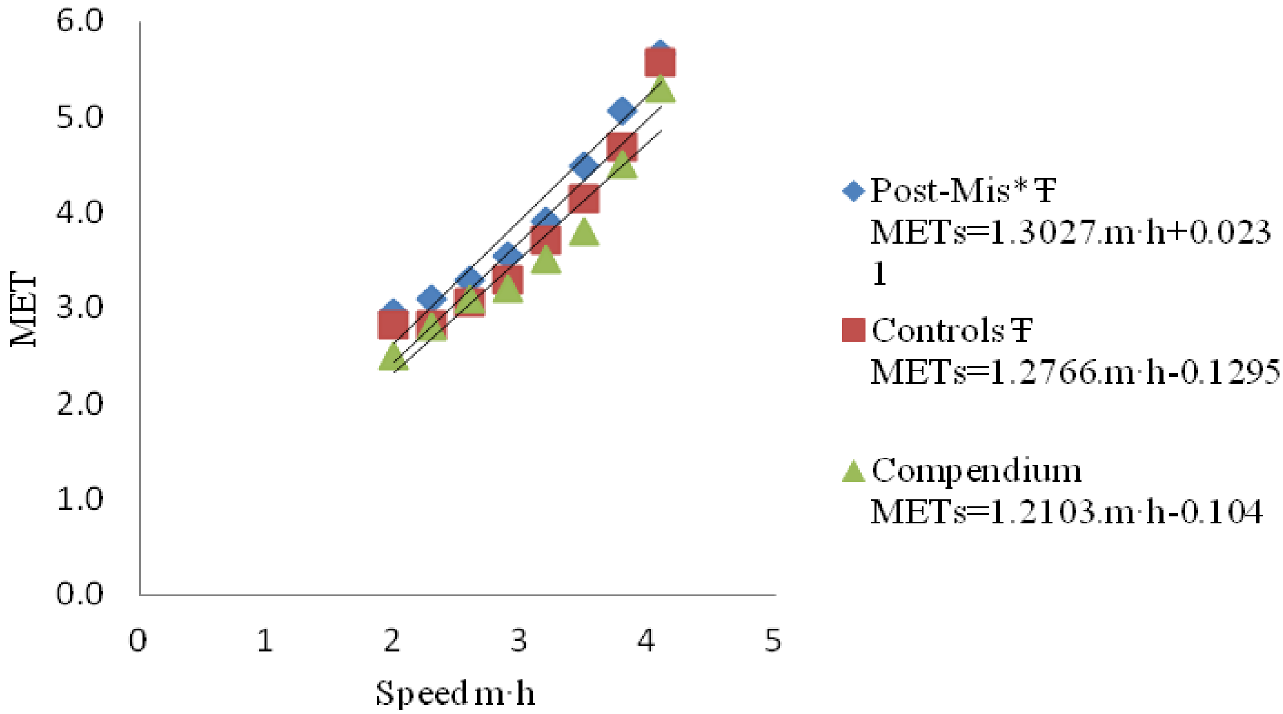

Figure 2. MET *vs.* Walking Speed Relationship during the GTWT for Post-MIs *vs*. Controls *vs.* Compendium Values. *Statistically significantly different from controls at P<0.05; ŦStatistically significantly different from compendium values at P<0.01.

DISCUSSION

The findings of this study indicated that compared to the controls the post-MIs VO_2 mL·kg^{-1}·min^{-1} and subsequent METs were significantly higher during the GTWT at walking speeds of 2.0 to 4.4 m·h^{-1}. It was unfortunate that the two groups were not matched for age and body mass, and while body mass was accounted for within the MET calculation, age was not. The increased mean age of the post-MIs may have been a contributing factor in the differences observed in METs between the groups. For example, Morris et al. (20) observed that between a group of non-cardiac patients, referred for other clinical reasons, and a group of apparently healthy individuals (mean age = 57, range 21 to 89 yrs), the decline in maximal HR and METs with age was steeped in the referral group.

Another contributing factor for the difference in METs between the post-MIs and the controls may be associated with the increased number of co-morbidities seen in the post-MIs. Peterson et al. (21) for instance considered the number of multiple co-morbidities to be the cause of difference in MET requirements when using a standard MET calculation, as opposed to a multiple of RMR. However, Byrne et al. (10) established that differences in body composition accounted for 62% of the variance in resting VO_2 measures in healthy men and women. It is difficult to determine if body composition was a contributing factor for the subjects in the present study since this variable was not accounted for. Nonetheless, similar to the findings of this study (see Figure 2), Bassett et al. (7) and Kozey et al. (16) both compared their measured MET values during various physical activities with reported compendium MET values (2) and observed over 60% of the physical activities tested resulted in significantly higher MET values than those indicated in the established MET tables.

Despite the post-MIs reporting higher PA levels than the controls, not all of the post-MIs reached stage 8 (4.1 $m \cdot h^{-1}$, Post-MI N = 15, controls N = 17) and stage 9 (4.4 $m \cdot h^{-1}$, post-MIs N = 7, controls N = 16). Superior levels of fitness have been shown to result in reduced oxygen consumption at comparable workloads (18,19), which was not seen in this study. However, if the post-MIs were indeed physically fitter than the controls of this study it may be that any physical fitness of the post-MIs was negated by the younger age of the controls.

None of the subjects exceeded 4.4 $m \cdot h^{-1}$ (7.8 $km \cdot h^{-1}$) during the GTWT. However, beyond 4.4 $m \cdot h^{-1}$ research has shown that participants find it more comfortable to run (22). Given the present study looked at walking, for some of the more capable subjects this might have been a limiting factor. However, in the study conducted by Woolf-May and Ferrett (29), none of the N = 31 male post-MI patients exceeded 4.16 $m \cdot h^{-1}$ (6.7 $km \cdot h^{-1}$) during the shuttle walking test (26). Yet, it is clear that the subjects' mean RER and RPE values during the final stages of the GTWT in the present study are consistent with the subjects functional peak rather a maximum (Table 3).

Table 3. RER and RPE Values during Final Stages of GTWT.

Variables	Post-MIs	Controls
Stage 8 (4.1 $m \cdot h^{-1}$) (6.6 $km \cdot h^{-1}$)	N = 15	N = 17
RER	0.96 ± 0.11	0.91 ± 0.06
RPE	13.7 ± 1.7	13.4 ± 1.1
Stage 9 (4.4 $m \cdot h^{-1}$) (7.8 $km \cdot h^{-1}$)	N = 7	N = 16
RER	0.93 ± 0.11	0.94 ± 0.05
RPE	14.3 ± 2.4	15.7 ± 2.5

Despite medications not having any statistically significant effect on VO_2 $mL \cdot kg^{-1} \cdot min^{-1}$, 82% of the subjects in the post-MI group were taking beta-blockers and while other studies have also found beta-blockers not to influence submaximal VO_2 (14,23), beta-blockers have been found to influence VO_2 max (23). Therefore, this variable may have affected the post-MIs ability to complete the latter stages of the GTWT.

In terms of the practical implications for prescribing exercise to post-MIs, by inserting walking speeds of 2, 3, and 4 $m \cdot h^{-1}$ into the equations given from each group (Figure 1), these would produce the MET values displayed in Table 4. For the post-MIs this would over prescribe the exercise intensity by around 0.5, 0.4, and 0.4 METs, respectively. Hence, it seems reasonable (for safety reasons) to take into consideration this "slight" adjustment in metabolic work for post-MIs when prescribing walking exercise based on the current compendium MET values.

Table 4. Walking METs Based on Individual Group Regression Equations.

Group	2 m·h^{-1}	3 m·h^{-1}	4 m·h^{-1}
Post-MIs	2.6	3.9	5.2
Controls	2.4	3.7	5.0
Compendium (REF)	2.1	3.5	4.8

CONCLUSIONS

When using the standard compendium 1 MET value to determine MET values during a GTWT, the post-MI subjects displayed significantly higher MET values compared to the subjects in the control group without CVD, and both post-MIs and controls individually showed significantly greater MET values compared to the current compendium MET values. In practical terms, these differences were less than 0.5 of a MET. Nonetheless, this difference should be considered when prescribing walking exercise based on current compendium MET values (particularly for high risk individuals in order to avoid over exertion).

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